from R7+R8) which was found in behavioral experiments by Kirschfeld [4] might thus be due to R7.

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1. Eckert, H.: Kybernetik *9*, 145 (1971)
2. McCann, G.D., Arnett, D.W.: J. Gen. Physiol. *59*, 534 (1972)
3. Harris, W., Stark, W.H., Walker, J.A.: J. Physiol. (in press)
4. Kirschfeld, K., Lutz, B.: Personal communication
5. Snyder, A.W., Pask, C.: J. Comp. Physiol. *84*, 59 (1973)
6. Langer, H., Thorell, B.: Exp. Cell Res. *41*, 673 (1966)

## Electric Signalling during Aggressive Behaviour in *Mormyrus rume* (Mormyridae, Teleostei)

Bernd Kramer*

Laboratoire de Physiologie Nerveuse, Département de Neurophysiologie Sensorielle, C.N.R.S. Gif-sur-Yvette, France, and
Universität Konstanz, Fachbereich Biologie, Konstanz, Federal Republic of Germany

In the mormyrid fish *Gnathonemus petersii*, rapid discharge rate accelerations and complex discharge patterns associated with butts, approaches, lateral displays, and fleeing behaviour were described (see [1–4]). There exists considerable evidence now that the electric organ may be used to communicate socially relevant signals to other individuals (additional literature in [5, 6]). The purpose of the present report is to furnish information on aggression-related electrical displays in another mormyrid fish species, *Mormyrus rume*. For methods, refer to [2].

Since there does not exist a method to reliably separate the discharges of two freely moving *M. rume* close in physical size and hence pulse amplitude, a closely related, sympatrically living [2] mormyrid, *G. petersii*, was used to elicit attacks by the *M. rume*.

The experiments were made with one *M. rume* (20.5 cm) and six *G. petersii* (15.5–20.5 cm). When one of the six *G. petersii* was put into the experimental tank where the *M. rume* was hiding in a tube of plastic mesh, the initially low and variable discharge rate (Fig. 1a, black histogram; mean: 6.7 Hz) rises to a mean 13.6 Hz (Fig. 1b). Furthermore, the principal mode of the resting histogram (approx. 105 ms) changes to approx. 63 ms in the aggression experiment. The latter mode is much more pronounced and clearly the only one in the distribution. The histogram displayed by an attacking *M. rume* is further characterized by the occurrence of very long intervals (up to 7.79 s) which are far beyond the range of intervals observed in isolated, resting (a, black) or swimming (a, white) conditions.

* Present address: Universität Konstanz, Fachbereich Biologie, D-7750 Konstanz, Postfach 7733, Federal Republic of Germany.

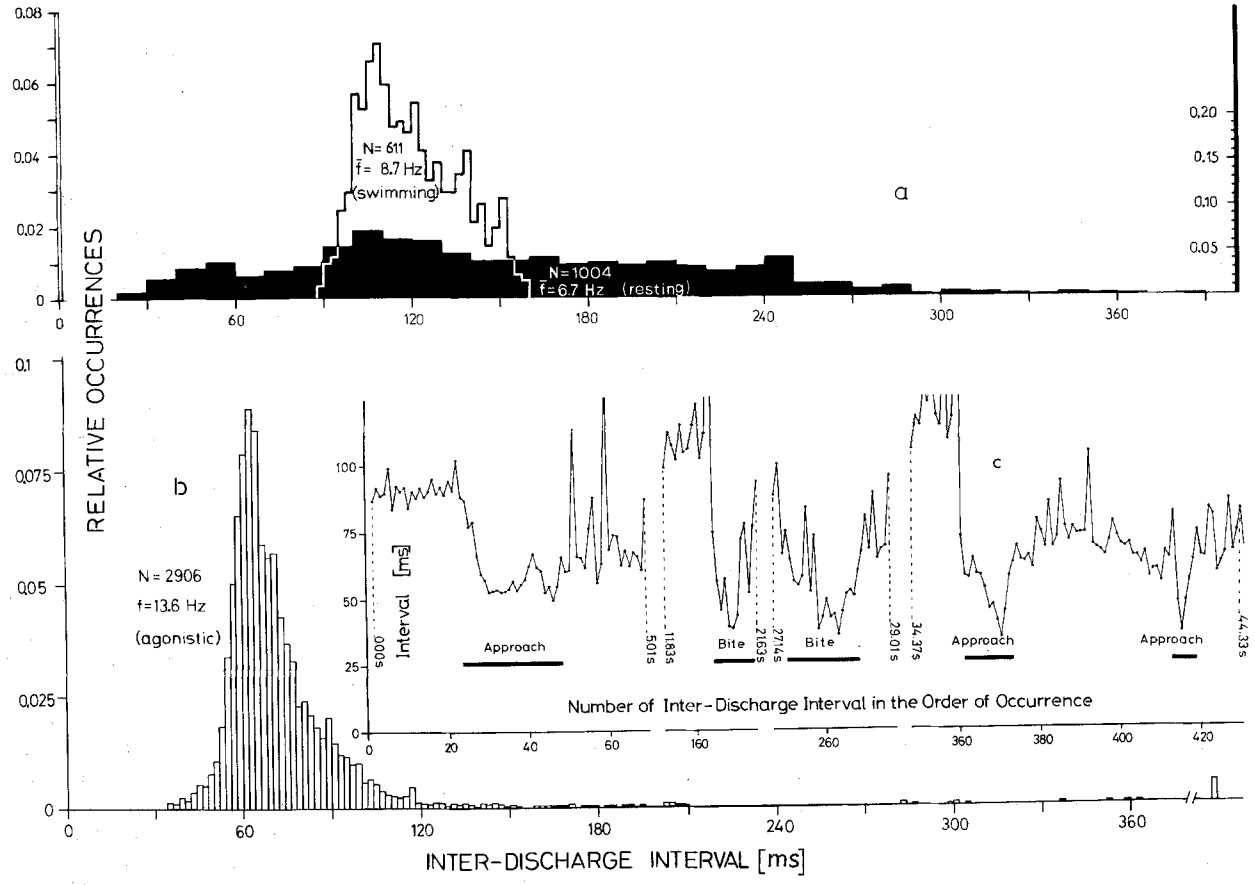


Fig. 1. (a) Interpulse-interval histograms of a resting (black) and a swimming (white) isolated *Mormyrus rume*. White ordinate indicates relative occurrences in white histogram, black ordinate in black histogram. $f$=mean discharge rate. Redrawn from [2]. (b) Interpulse-interval histogram of a resident *M. rume*, attacking another mormyrid. Note sharp mode at high discharge rate and extremely high variability of interval lengths (up to several seconds) as compared to (a). The three histograms are normalized to cover the same area, i.e., equal areas are the same densities of probability. (c) Sequential representation of discharge activity of aggressive *M. rume*. Each point is one interval, plotted sequentially on the abscissa. The ordinate is the length of each interval. Note that during overt attack interval length decreases rapidly (i.e., discharge rate rises). Periods without attacks and discharge-rate accelerations are left out as indicated

 

The discharge activity of *M. rume* just before, during, and between attacks is shown in Fig. 1c. Before an attack, the duration of intervals is between 60 and 100 ms, with some longer intervals distributed among them. During the approach of the opponent, interval length diminishes rapidly (discharge rate accelerates). Within 2–8 intervals, the highest discharge rate is reached. The shortest interval, displayed during an attack, was between 34 and 56 ms in these experiments. *M. rume* does not seem to possess the ability to maintain its high discharge rate for more than about 5 intervals. The discharge rhythms displayed during swimming, resting, and inter-burst agonistic activity exhibit opposite kinds of successive interval length regulation in the two species [2]. It is interesting to note that the discharge pattern recorded during overt attack is an exception to this rule. This might indicate that an attack-associated discharge-rate acceleration is mutually understood as an aggressive signal by the two species of fish.

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1. Scheich, H., Bullock, T.H., in: Handbook of Sensory Physiology, Vol. III/3, p. 201 (ed. by A. Fessard). Berlin-Heidelberg-New York: Springer 1974
2. Kramer, B.: J. Comp. Physiol. *93*, 203 (1974)
3. Bauer, R.: Behaviour *50*, 306 (1974)
4. Kramer, B.: ibid. (in press)
5. Westby, G.W.M.: J. Comp. Physiol. *96*, 307 (1975)
6. Hopkins, C.D.: Z. Tierpsychol. *35*, 518 (1975)

## Olfactory Orientation in Frogs

K. Müller and J. Kiepenheuer

Fachbereich Biologie der Universität Regensburg

Electrophysiologic experiments suggest a well-functioning sense of smell in frogs [1]. To date, in behavioral experiments no reaction to odors has been obtained. This paper shows that *Rana temporaria* obviously is capable of olfactory orientation.

The following odors were presented to 4 ♂♂ and 2 ♀♀: A complex odor (manufactured by Fribad, Baden-Baden) as well as its individual components: Mixture PB 1986/8 (Givaudan, Switzerland), chloroacetamide, allantoin, potassium sorbate, polyacrylic acid, triethanolamine, cetiol, isopropyl myristate, mygliol, nipasol; further, the substances amylacetate, heptanal, and pyrrole, which were not part of the complex odor. The testing apparatus consisted of a circular drum (diameter 43.5 cm, rim 16 cm high), which was divided into 12 sectors. In each sector at the rim there was a little flask containing a strip of filter paper. When odors were tested one of the filter papers was soaked with one of the substances. All experiments were conducted in a dark room with a dim light centered above the testing drum.

For the experiments, a frog was set into the center of the drum. Five min later the sector of the drum was recorded in which the animal stayed. Then the animal was removed. After a waiting period of another 5 min the test was repeated. During one experiment each animal had 12 trials. In each trial the initial direction of the animal with respect to the room was kept constant and between trials the drum was rotated.

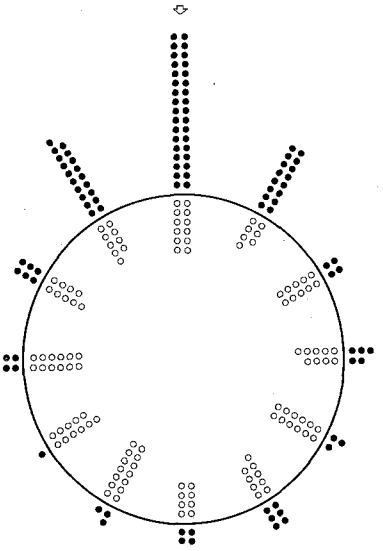

Fig. 1. *R. temporaria* ♂♂. Controls showed an equal distribution along the periphery of the testing drum (*open circles*). Mixture PB 1986/8 was preferred significantly (*solid circles*). The source of odor is indicated by an arrow

In 144 control trials no odor was presented. The animals moved towards and then along the periphery of the drum and settled down there. The locations of the animals at the periphery of the drum showed a random distribution (Fig. 1, *open circles*). On the average an animal stayed 30 sec in one place. No orientation with respect to the drum or the room could be detected (mean vector length: $R/n=0.04$ [2]).

When the complex odor was presented ♂♂ were found in the sector with the source of the smell or in the two adjacent ones in 66% of all trials (75% for ♀♀); $R/n$ for ♂♂ $=0.53$, $n=105$, for ♀♀ $R/n=0.67$, $n=24$.

When Mixture PB 1986/8 was presented, the ♂♂ were found in 83% ($R/n=0.76$, $n=126$) of all trials near the source of smell; statistical significance with $p<0.01$ (Fig. 1, *solid circles*).

When the scheme 5 min testing time and 5 min waiting time was abandoned the animals stayed 30 min or longer next to the source of odor. In addition typical digging movements could be observed there.

No reactions could be observed to the other components of the complex odor. All experiments resulted in a random distribution as in the controls. This is also true for amylacetate, heptanal and pyrrole, though they are very effective odors in electrophysiologic experiments.

In another series of experiments mixture PB 1986/8 was offered in six different concentrations: pure mixture, 10-, $10^2$-, $10^3$-, $5\times10^3$-, and $10^4$-times dilution with paraffin oil. Corresponding to these concentrations the animals stayed next to the source of odor in 83% ($R/n=0.76$, $n=126$), 81% ($R/n=0.76$, $n=36$), 74% ($R/n=0.68$, $n=23$), 72% ($R/n=0.66$, $n=36$), 56% ($R/n=0.46$, $n=36$), and 25% ($R/n=0.20$, $n=24$). All results, except the last one, are statistically significant with $p<0.01$.

Thus far frogs were only known to orientate to acoustical and optical stimuli. They were not known to be capable of olfactory orientation. During the experiments precautions were taken that neither acoustical nor optical orientation was possible. Therefore, the behavior of *R. temporaria* during the

  